the polar curve

Mark Andrews examines the rudiments of sink rate and speed

The use of the polar curve to calculate the best speed to fly in different conditions is not well explained in many paragliding and hang gliding texts, since its explanation is mathematical and publishers never like too much maths in books. So here goes. Some simple algebra will be necessary to explain what the polar curve is and how we can use it, but more importantly what practical lessons it can teach us to improve our flying.

In still air we can measure the sink rate of a glider at various speeds. Nowadays this can be done with some degree of accuracy using a GPS. Since the sink rate is a negative number and it is dependent on the airspeed we get the typical layout of the axes as shown in fig 1, with the sink rate on the vertical axis and the speed on the horizontal axis. This is the typical diagram you will find in any free flight text book. (In still air, airspeed and ground speed are identical. We label the horizontal axis as groundspeed since this is what interests us when we interpret the polar curve.)

Looking at the curve you will see four speeds marked:

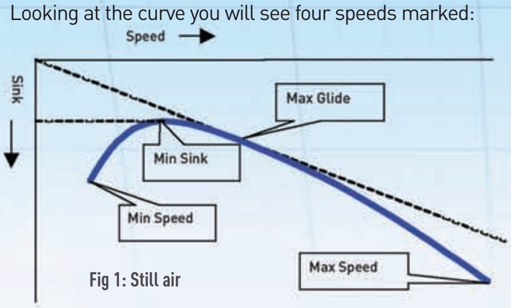

Fig 1: Still air

Min. speed (stall speed) - the speed at which your glider stops flying.

Min. sink - the optimum speed that minimises the sink rate.

Max. speed - the maximum speed at which the glider will fly.

Max. glide - the speed that will allow a paraglider to travel the furthest distance.

Of these, max glide is the only speed that may be tricky to determine. Many paragliding books will tell you how to find it ("Draw a line from the origin of the graph to the polar curve"), but few explain why or how this generates the max. glide speed. It is simply stated, so let's see how drawing a tangent to the curve through the origin generates max. glide. (Warning: maths content approaching!)

Let's consider a simple example to throw some light on the matter.

How would we calculate our glide ratio if we were at 100ft, sinking at 5ft/s, with a horizontal speed of 25ft/s?

If we were at 100ft sinking at 5ft/s, we could expect to meet the ground 20 seconds later, since:

Height / Sink rate = Sink time (a)

But in that 20 seconds we have moved forwards. Moving 25ft every second for 20s we cover 500ft, since:

Sink time x Speed = Distance (b)

So we have dropped 100ft and covered 500ft. Our glide ratio is therefore 5:1, since:

Glide ratio = Distance / Height (c)

Combining (a) and (b) gives us:

(Height / Sink rate) / Speed = Distance (d)

Combining (c) and (d) we get:

Glide ratio = [(Height / Sink rate) / Speed) / Height (e)

Or, Glide ratio = Speed / Sink rate (f)

So in our question we could have simply divided our speed (25ft/s) by our sink rate, (5ft/s) to get a glide ratio of 5:1

On the graph our glide ratio will be indicated by drawing a line from the origin to the polar curve, because this line expresses the ratio between speed and sink rate.

Our best glide ratio will give us our max. glide. On the graph this will occur when ratio of speed to sink rate is greatest. This is simply when the line joining the polar curve to the origin is at its shallowest. This indicates our max glide speed in still air.

The polar curve therefore gives us a useful profile of a wing's performance at different speeds, and can provide us with the best speed to fly if we want to fly the furthest distance (Max. Glide). It can also be used for sinking air, tailwinds and headwinds.

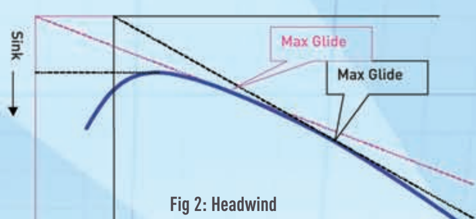

Fig 2: Headwind

In a headwind groundspeed is reduced. This effectively shifts the sink axis to the right (the degree of shift being the value of the headwind) and reduces the groundspeed values for Min. sink, Min, speed and Max. speed. In this diagram, flying at the minimum speed (just above stall) would have you drifting backwards. Max. glide remains at the intersection between the curve and the new origin and shifts relative to the other speeds. The new Max. glide shifts further down the curve, corresponding to the higher speed needed to make best distance over the ground.

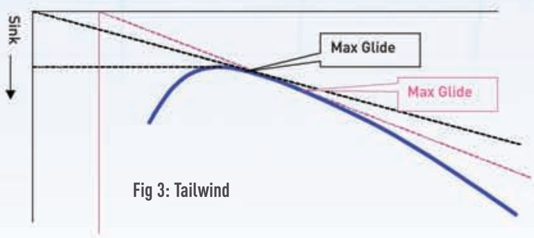

Fig 3: Tailwind

In a tailwind groundspeed is increased. This has the effect of shifting the sink axis to the left, increasing the groundspeed values for Min. sink, Min. speed and Max. speed. In this case the new Max. glide is shifted further up the curve, corresponding to the slightly lower speed needed to make best distance over the ground.

To sum up, in a tailwind Max. glide is nearer to Min. sink airspeed; in a headwind it is nearer to Max. speed. If we are aiming to achieve our best possible glide over the ground we should always speed up into wind and slow down when flying downwind. However in a tailwind there is never an advantage flying slower than Min. sink.

- Speed up in a headwind
- Slow down in a tailwind
- Never fly slower than Min. sink

Well that's the theory, but what about real flying? It is possible to use a GPS and fly in still morning air to get a plot of the polar curve for your wing, but it's really not worth the effort. The best way to regularly achieve more efficient glides is to fly with a GPS displaying your actual glide ratio. Adjusting your airspeed will quickly give you the most efficient glide.

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